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Studies were conducted throughout Republic of Korea (ROK) to better characterize the distribution of militarily important human infections with hantaviruses, leptospira, scrub typhus, murine typhus and a Colorado tick fever-like agent; to systematically describe the prevalence of infection in rodent and human populations, relating ecology, ectoparasite and rodent population dynamics to transmission and maintenance of infection; to identify risk factors for acquisition of human disease with the above agents.

A case control study of risk factors for acquiring KHF-like illness conducted in ROK soldiers showed increased risk of acquiring KHF associated with sleeping in tents and other primitive dwellings; living in dwellings with dirt floor; digging trenches; sightings of Apodemus; and the use of camouflage. Helping local farmers harvest rice did not increase KHF risk.

Examination of 5947 serum specimens from civilian and ROK military patients with hemorrhagic manifestations determined the etiology as HFRS in 14%, scrub typhus in 18%,

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while the etiology remained unknown in 59% of patients. Most patients were identified in Seoul city and the northern and south-western provinces of South Korea in the fall, however small numbers of cases occurred throughout the year.

A serosurvey of 3912 active duty ROK Army soldiers demonstrated antibodies for hantavirus in 1.6% with soldiers of rural origin being seropositive more often than soldiers of urban origin. Additionally a cohort of hepatitis A susceptible young adults was identified.

Scrub typhus transmission in an urban setting was recognized in rapidly developing Chinhae and Koje Island. R tsutsugamushi-infected chigger mites may persist with their rodent hosts in areas where urban development encroaches on former scrub habitat, posing an ongoing transmission risk of scrub typhus to humans.

An extensive geozoological survey found the majority of mammals trapped were Apodemus agrarius; grass and scrub areas are the major habitat; populations expand dramatically in fall corresponding to the fall Hantaan virus epidemic season. In-utero, post partum or transmission by milk apparently does not play a role in the maintenance of the virus in Apodemus and aerosol or arthropod transmission is not the primary route of infection in nature. The risk of acquiring a Hantaan virus infection is highest in grassy or scrub areas but there is a risk to military personnel in any habitat, anywhere within ROK.

While it is well documented that urban rats do play an important role, our studies suggest that neither domestic farm animals nor sylvatic mammals play an important role in maintenance or transmission of leptospirosis in the ROK.

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Summary

A case control study of risk factors for acquiring KHF-like illness was conducted in ROK soldiers between 1 Nov 89 and 15 Jan 92. Korean Hemorrhagic Fever was confirmed in 212 ROK soldiers during the study; 177 of 196 cases available for interview were matched with controls for analysis. Increased risk (odds ratio and 95% confidence interval) of acquiring KHF was associated with sleeping in tents (3 [1.7-5.1]) and other primitive dwellings (7 [2.2-23]); living in dwellings with dirt floor (7.4 [0.9-65]); digging trenches (2.0 [1.3-3]); sightings of Apodemus (4.7 [1.5-14]); and the use of camouflage (1.4 [0.9-2.1]). Helping local farmers harvest rice did not increase KHF risk. No meaningful differences in activities could be recognized between the 8 soldiers with confirmed leptospirosis and 14 with confirmed scrub typhus and soldiers who did not develop disease.

From 5947 serum specimens from civilian and ROK military patients with hemorrhagic manifestations examined at the Institute for Viral Diseases in 1990-1, 838 cases of HFRS, 1060 cases of scrub typhus, 348 cases of murine typhus, 59 cases of spotted fever and 155 cases of leptospirosis were confirmed. The etiology remained unknown in 59% of patients. Most patients were identified in Seoul city and the northern and south-western provinces of South Korea. Most cases of HFRS, murine typhus, scrub typhus and leptospirosis occurred in the fall, however small numbers of cases occurred throughout the year.

Seroprevalence for hantavirus antibodies was determined in 3912 active duty ROK Army soldiers in summer 1991. Sixty-two soldiers (1.6%) had antibodies (3/107 officers [2.8%] and 59/3805 enlisted [1.55%], p=NS). Soldiers of rural origin were seropositive more often than soldiers of urban origin (25/930 [2.7%] versus 37/2944 [1.26%], $p<0.005$). Seropositivity to hantavirus was significantly related to age, rank, and length of service. Additionally, 18 of 100 of the above sera screened at random for hepatitis A antibodies had no IgG anti-HAV antibodies detectable. Although hepatitis A has not been a clinical problem in South Korea to date, a cohort of hepatitis A susceptible young adults is emerging.

Scrub typhus transmission in an urban setting was recognized in rapidly developing Chinhae and Koje Island. *R tsutsugamushi*-infected chigger mites may persist with their rodent hosts in areas where urban development encroaches on former scrub habitat, posing an ongoing transmission risk of scrub typhus to humans. Therefore, we recommend that scrub typhus be considered in patients who present in the fall in Republic of Korea with abrupt fever, chills, headache and rash, even though they have no known exposure to scrub habitat.

A total of 1,675 mammals were collected during the geozoological survey. The majority of mammals trapped were *Apodemus agrarius*; the majority were trapped and most of the rodent burrows were observed in grassy and scrub areas. During the fall, *Apodemus* populations expand dramatically to provide enough individuals to overwinter. This expansion of *Apodemus* populations also corresponds to the fall HTNV epidemic season. Adult males are seropositive to HTNV more than twice as often as females (OR 2.6 [1.6-4.5], $p<0.001$); no juvenile and few sub-adults had HTNV antibodies. These data suggest that in-utero, post partum or transmission by milk does not play a role in the maintenance of the virus in *Apodemus* and that aerosol or arthropod transmission is not the primary route of infection in nature. The risk of acquiring a HTNV infection is highest in grassy or scrub areas but there is a risk to military personnel in any habitat, anywhere within ROK.

While it is well documented that urban rats do play an important role, our studies suggest that neither domestic farm animals nor sylvatic mammals play an important role in maintenance or transmission of leptospirosis in the ROK.

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INTRODUCTION

Background

The ecology of South Korea has changed markedly since the end of hostilities in 1954. Reforestation, resumption of organized farming, and human encroachment have altered the human/rodent relationship with resultant alteration in human exposure to infectious agents maintained either directly or indirectly by rodent hosts. HW Lee and colleagues have established the importance of hantaviruses (Hantaan, Seoul, and related viruses) in the causation of widespread human disease in Korea, as well as elsewhere in Asia [1]. Other rodent-borne pathogens, especially leptospirosis and scrub typhus, have only recently been recognized as major health problems in Republic of Korea [2,3]. Studies conducted under USAMRDC grant DAMD-17-86-G- 6011 "Hemorrhagic fever with renal syndrome (HFRS)" identify leptospirosis, scrub typhus, and perhaps Colorado tick fever (CTF) or a closely related virus, as important causes of human disease among some populations in Korea, including military units, which on initial clinical diagnosis have been confused with HFRS.

Historically leptospirosis and scrub typhus have both been important human diseases of proven importance to the military; they occur most commonly in developing countries of the world where research capabilities are limited. Consequently, these diseases have not benefitted from the current revolution in biotechnology, nor has our understanding of their epidemiological characteristics progressed significantly over the past decades.

Previous Work

The extent of the human disease burden due to leptospirosis in Korea was not well characterized, due in part to the absence of careful scientific investigations in this disease, and to the absence of convenient diagnostic tests to rapidly identify acute infections. Graham has developed a sensitive, specific assay that can rapidly diagnose acute leptospirosis infections, estimate the prevalence of specific antibodies to leptospiral antigens in survey populations, and function well in human pathogenic serovars known to occur in Korea and worldwide.

Although *Rickettsia tsutsugamushi* was isolated from field mice during the Korean Conflict, little has been done to investigate the epidemiological characteristics of this disease. Scrub typhus was not recognized clinically in Republic of Korea until Lee's report in 1984 [4]. Changes in the ecological conditions in Korea since the Korean Conflict and modifications in agricultural practices suggest that the current disease ecology may be quite different from those observed during investigations made during and after the Korean Conflict.

Colorado tick fever has never been recognized as a human pathogen in Asia; however, the studies above which examined Hantaan seronegative patients with a clinical diagnosis of KHF revealed many sera contained antibodies specific for a virus identical or closely related to CTF. C Calisher of CDC, Fort Collins, confirmed these observations by virus neutralization tests. These suggested that perhaps an heretofore unrecognized viral pathogen exists in Korea which could be responsible for a portion of the KHF-like clinical disease for which no etiologic diagnosis can be found.

Objectives

We conducted studies throughout Republic of Korea (ROK) to better characterize the distribution of human infections with leptospira, scrub typhus, murine typhus and a Colorado tick fever-like agent; to systematically describe the prevalence of infection in rodent and human populations, relating ecology, ectoparasite and rodent population dynamics to transmission and maintenance of infection; to identify risk factors for acquisition of human disease with the above agents.

MATERIALS AND METHODS

A. Epidemiology

1. Case Control Study of Risk Factors

We conducted a retrospective case-control study from 1 Nov 89 to 15 Jan 92 in ROK soldiers admitted with the presumptive diagnosis of KHF, scrub typhus, leptospirosis, or an acute undifferentiated febrile illness to the Capital Armed Forces General Hospital, Seoul, Korea, under protocols approved by Korean and US human use review committees. All ROK armed forces personnel throughout the Republic of Korea who develop a KHF-like illness are hospitalized directly at or transferred to the Capital Armed Forces General Hospital (CAFGH). Patients with clinical diagnoses of leptospirosis or scrub typhus are generally managed at their local medical unit, so patients with these diagnoses at the CAFGH were from the Seoul area or had complications. Blood, urine, and acute and convalescent sera from patients were submitted to the microbiology laboratory at USAMRU-ROK for diagnosis by attempted isolation or demonstration of antibodies to the agents above. A questionnaire was administered by an Epidemiology team member to facilitate and make consistent the interview process for these soldiers. The questions included background demographic data (age, MOS, unit, point of entry and duration of service, etc). The soldiers were asked the number of different places that they had lived in over the past 2 months. For each location the soldiers were asked: types of dwellings; types of activities that they performed; whether they had contact with water, dust, rodents or insects, as well as other possible risk factors for the diseases under study.

To control for potential confounders, controls for the study were randomly recruited from ROK soldiers admitted to the same hospital on the same date of each case, plus or minus 5 days. The nurse epidemiologists interviewed soldiers without knowing whether the soldiers were cases or controls. After the interview, the nurse epidemiologists and an epidemiology supervisor reviewed the interviews for completeness, discrepancies or inconsistencies.

Odds ratios and 95% confidence intervals (CI95) were calculated for each risk factor by univariate analysis. Potential confounders were controlled for by stratification by risk factor using the Mantel Haenszel method to obtain odds ratios and CI95. Relative contribution of each risk factor identified will be made by multiple logistic regression analysis.

2. Serum specimens from civilian and military hospitals

Serum specimens from civilian and military hospitals throughout Korea were submitted to the Institute for Viral Diseases for diagnosis of suspected KHF. These specimens were anonymously tested for *R tsutsugamushi, R typhi, R siberica* and leptospirosis to give additional valuable clues to the spatial and temporal distribution of human pathogens in the Republic of Korea.

3. Serosurvey of ROK Army Personnel

ROK AFMC Preventive Medicine department conducted a serosurvey in 3912 active duty ROK Army soldiers in Kyonggi (near the Demilitarized Zone) and Chungnam (central ROK) provinces during a two week period in summer 1991. Sera were processed in the field and brought to USAMRU-ROK for storage at minus 70°C for later detection of antibodies to Hantaan virus, rickettsiae, leptospirae, and CTF; demographic data were analyzed.

4. Urban scrub typhus

Patients with a recent clinical diagnosis of scrub typhus in fall 1991 at the Chinhae Community Hospital were interviewed at their homes to characterize possible disease exposure sites. Charts of patients with a clinical diagnosis of scrub typhus were reviewed for the 1990 and 1991 transmission seasons at the two regional hospitals on Koje Island, adjacent to Chinhae. Population data were provided by the Ministry of Home Affairs. Field and house rodents were trapped as in B,2 below.

B. Field Ecology and Microbiology

1. Survey Area

A geozoological survey extending throughout the ROK which samples relevant geographical areas in a 50 km grid has been started (Figure 1). The site locations are detailed in Table 15. Each area is sampled by trap lines which transect all ecological settings at the site. Trapped mammal populations were identified to species and enumerated by age and sex. Meteorological and ecological data was also collected from each site.

2. Collection of Field Mammals

Field and house rodents were captured by means of baited Sherman and Tomahawk traps [5,6]. The rodents were identified to species and processed under CO_2 anesthesia. Serum was collected for serological testing for Hantaan virus, rickettsial agents, and Colorado tick fever (CTF). Tissue samples for isolation of HTNV, scrub typhus, and leptospirosis included lung, kidneys, liver, spleen and lymph node. One kidney was processed in the field for leptospirosis isolation. The rest of the tissue was stored at -70° C. All rodent ectoparasites were collected both in alcohol for identification and frozen for isolation attempts.

3. Taxonomic studies on *Apodemus* in Korea

A collaborative study has been started with the Carnegie Museum of Natural History in Pittsburgh Pennsylvania. The purpose of this study is to clarify the species and sub-species *Apodemus* occurring in the ROK. Detailed morphometric measurements and iso-enzyme studies will be done on specimens from selected sites from the geozoological survey.

4. Specimens from Patients

Blood, urine or necropsy tissue were collected from acute phase patients for isolation of virus, leptospira, or rickettsia and sera were collected from suspected leptospira, CTF, or rickettsial patients for serodiagnosis. Larger amounts of hyperimmune convalescent serum were collected when possible for experimental purposes.

5. Virus Isolation

Details of techniques for isolation of CTF and related viruses in suckling mice and Vero cells have been described previously [7].

6. Leptospiral Isolation

Blood, urine or tissue samples were triturated and inoculated into EMJH media as described previously [8]. All positive cultures are identified by standard serological techniques and representative cultures have been sent to the WHO Leptospirosis Laboratory at CDC.

7. Rickettsial Isolation

The isolation of scrub typhus from blood, tissue and chigger samples in ICR adult mice has been previously detailed [9]. Isolates were identified by standard serological techniques.

8. Serological Tests for Leptospiral Antibodies

An ELISA for leptospiral IgG and IgM antibodies developed at USAMRIID is being used for serological tests in humans. Since this test is relatively new and the prevalence of different leptospiral serovars, besides Mwogola is presently unknown, a microagglutination test (MAT) [8] is also used in conjunction with the ELISA. Representative serovars from each serogroup are being used. As more serovars are isolated from human and domestic animals studies they will be added to the MAT test to provide a more relevant test.

All serological studies in domestic animals will be done by MAT until the ELISA test is developed for these species.

9. Serological Test for rickettsial antibodies.

All serology utilizes established IFAT techniques using yolk sac antigen [10]. Samples are considered serologically positive when the titer is greater than 1:40.

10. Serological Tests for CTF like Agent

Serological testing for CTF-like agents will be done by IFAT [11] and confirmed by plaque reduction neutralization (PRNT).

RESULTS

A. Epidemiology

1. Case Control Study of Risk Factors

a. Hantavirus infections

Two hundred and twelve ROK soldiers had serologically confirmed Korean Hemorrhagic Fever during the study period 1 Nov 89 and 15 Jan 92; 196 were available for interview and completion of the study questionnaire: 177 cases with 178 matched controls were analyzed; the remaining 19 cases were omitted because they were other than army or occurred in the off-season and suitable controls were not available. The median age for cases and controls was 21 years.

Activities associated with increased risk of acquiring KHF with odds ratios [OR] and 95% confidence limits [CI95] were: sleeping in tents, 3.0 (1.7-5.1); sleeping in other primitive dwellings, 7.0 (2.2-22.6); living in dwellings with dirt floor, 7.4 (0.9-64.8); digging trenches, 2.0 (1.3-3.0); sightings of Apodemus, 4.7 (1.5-14.2); and the use of camouflage, 1.4 (0.9-2.1).

Activities associated with reduced risk of acquiring KHF were: basic training 0.6 (0.4-1.0); sightings of rats 0.7 (0.5-1.2).

Activities like helping local farmers harvest rice were expected to have increased risk because of potential aerosolization of Apodemus excreta in the vicinity, but proved to have no added risk.

b. Leptospirosis

All eight Leptospirosis patients were young male ROK soldiers (mean age=21.0) (Table 1). Six (75%) were combat arms soldiers. Seven (88%) were exposed to the field before they became sick. Six (75%) reported substantial exposure to ground water or mud (creeping/crawling, crossing a stream, doing repair work or while helping with rice harvesting). Six (75%) reported having scratched skin or abrasions. Of the six reporting abrasions, five reported being exposed to ground water or mud. Five (63%) reported a history of athlete's foot at their last location and 4 of those 5 were exposed to ground water or mud.

Five (63%) obtained their water from a water supply facility and three (38%) from a well with pump. Only one (13%) reported having any intra-oral lesions.

The similarity of activities of soldiers who did or did not develop leptospirosis, and the small number of those who did in this sample, prevent drawing meaningful conclusions about specific risk factors for acquiring disease.

c. Scrub Typhus

All of the confirmed scrub typhus patients were young males (mean age=21.7)(Table 2). Twelve of the fourteen (86%) were combat arms soldiers. During their resting periods, nine (64%) reported sitting in the dirt: eight (57%) reported sitting on the grass; and five (36%) reported lying on the grass. Five (36%) reported playing on the parade ground. Three (21%) reported using camouflage.

As with leptospirosis above, it is not possible from this sample to draw meaningful conclusions about specific risk factors for acquiring scrub typhus.

2. Diagnostic Serology on Specimens Submitted by Civilian and ROK military Hospitals in Korea in 1991

The total number of serum specimens from civilian and ROK military patients with hemorrhagic manifestations examined for Hantaan virus, *Rickettsia tsutsugamushi*, *R typhi*, *R Siberica* and Leptospirosis at the Institute for Viral Diseases in 1991 was 2679. There were 374 cases of HFRS, 377 cases of scrub typhus, 150 cases of murine typhus, 10 cases of spotted fever and 15 cases of leptospirosis confirmed serologically among these suspect hemorrhagic disease patients. The percentage of serologically confirmed patients among clinically suspected patients are shown in Table 3. It is noteworthy that the etiology of 65% of the clinically suspected hemorrhagic disease patients was unknown by the methods employed in the study.

The geographical occurrence of HFRS, murine typhus, scrub typhus, spotted fever and leptospirosis is shown in Table 4. The majority of the hemorrhagic disease patients were identified in Seoul city, Kyunggido, Chungcheongnamdo, Jeollabukdo, Kangwando and the northern and southern-western parts of South Korea. Monthly incidence of HFRS, murine typhus, scrub typhus, spotted fever and leptospirosis is shown in Table 5. Outbreaks of HFRS, murine typhus, scrub typhus and leptospirosis occurred in the fall of 1991 during epidemic season of HFRS; however small number of patients occur throughout the year.

3. Serosurvey of ROK Army Personnel

Sera were obtained from 3912 active duty ROK Army soldiers during a two week period in summer 1991; 1900 in Kyonggi-do (near the Demilitarized Zone) and 2012 in Chungnam-do (central ROK) provinces. Mean age of the soldiers was 21.5yrs (range 18-47yrs); the 107 officers were older than the 3805 enlisted (25.8yrs versus 21.4yrs).

Seroprevalence for hantavirus antibodies was 1.6% (3/107 officers [2.8%] and 59/3805 enlisted [1.55%], p=NS; geometric mean titer = 1107). IgM antibodies to

hantavirus were detected at >1:100 dilution (GMT = 419) in the sera of 15 of these 62 soldiers. Two of the soldiers with IgM antibody had KHF and were included in the case-control study, one had received Hantavax, and 8 of the remaining 12 who could be contacted had no known febrile illness of consequence during the previous two years. (Note: 8 of 11 patients with serologically proved KHF in the case-control study above still had IgM antibodies detectable at >1:100 dilution over 18 months after their acute illness).

Soldiers whose origin was rural were seropositive for hantavirus antibodies more often than soldiers of urban origin (25/930 [2.7%] versus 37/2944 [1.26%], $p<0.005$). Seropositivity to hantavirus was significantly related to age, rank, and length of service (latter two are markers for age). We conclude that prevalence of pre-existing antibodies to hantaviruses in ROK soldiers is sufficiently low, even in soldiers from rural areas, that screening volunteers for participation in a KHF vaccine field trial would not be necessary.

Eighteen of 100 sera screened at random for hepatitis A antibodies had no detectable IgG anti-HAV antibodies present. Hepatitis A has not been a clinical problem in South Korea to date, but an emerging cohort of hepatitis A-naive young adults would be expected to accompany the rapid development that has occurred here; these results support that hypothesis.

4. Urban scrub typhus

Eight recently recovered scrub typhus patients were visited at their homes in Chinhae and on Koje Island. All 8 lived in an urban setting; two lived in high-rise apartment complexes. Three patients recalled no activity that might bring them into contact with chigger mites; one was a shipyard worker, one picnicked on a small patch of grass adjacent to her apartment and one only walked a dirt path across a vacant lot to market near her house. Five thought their exposure occurred while working in small garden plots or golfing. One 3x5m garden plot was within the home wall; the others were grouped in small vacant lots between buildings. (Ancestral burial mounds are typically grassy areas in cleared scrub on the periphery of urban as well as rural settlements. Visiting these sites and picnicking on the grass is common family practice after the summer rains are over).

Seventeen *Apodemus agrarius* trapped in the immediate vicinity of the patients' homes in December had serum antibodies to *Rickettsia tsutsugamushi*. No Rattus spp were trapped.

140 patient records were reviewed (51 from 1990; 89 from 1991); 91 from Okpo-Daewoo Hospital, Jangseungpo-shi, and 49 from Koje Christian Hospital, Koje-gun. The Okpo-Daewoo Hospital, built 9 years ago, serves one-tenth of the land mass and one-half of the population of Koje Island in the rapidly developing Jangseungpo city; the population served are mostly shipyard and company workers. Koje Christian Hospital serves the remainder of the island with long established farm lands and small suburban communities; about half the families served are farmers. Incidence overall was 63 cases/100,000 population/year for 1991 (114/100k/yr Jangseungpo-shi and 35/100k/yr Koje-gun). The majority of cases occurred from mid-October to mid-November (range end-September through second week in December); one case occurred early August and 2 cases occurred the first week of January. Forty-six

percent of patients were male and 54% were female; mean age 38.4 (range 1.3-80 yrs). Mean prodrome length reported was six days (1-17d); a rash was noted in 115 (82%); an eschar in 93 (66%); and regional lymphadenitis in 8 (6%). Hospitalization duration ranged from one to nineteen days (mean 5.1, mode 4); patients over 50 years of age were more likely to be hospitalized five or more days (odds ratio =4.5 [95% confidence interval 1.9-11]); there was no association between the length of prodrome and hospitalization duration. Hepatitis was the admitting clinical diagnosis in 28 patients (20%). There were no deaths.

Results are pending for an anonymous serosurvey for antibodies to *Rickettsia tsutsugamushi* and *R typhi* performed on excess serum from routine determinations provided at random by the clinical laboratories at the four regional hospitals in Chinhae and on Koje Island provided

Our data show that *R tsutsugamushi*-infected chigger mites may persist with their rodent hosts in areas where urban development encroaches on former scrub habitat, posing an ongoing transmission risk of scrub typhus to humans. Therefore, we recommend that scrub typhus be considered in patients who present in the fall in Republic of Korea with abrupt fever, chills, headache and rash, even though they have no known exposure to scrub habitat.

B. Field Ecology

A total of 1,675 mammals were collected during the geozoological survey. The species collected and the antibody distribution are detailed in Table 7. Table 8 details the field site locations and HTNV and scrub antibody results from each site. The majority of mammals trapped were *Apodemus agrarius*. Identification to sub-species was not possible except in the case of *A agrarius mantchuricus*. A total of 226 *Apodemus* have been further processed and the skulls and study skins along with the iso-enzyme data will be forwarded to the Carnegie Museum for further analysis.

Apodemus were found in all habitats sampled (Table 9) but the majority were trapped in grassy areas and this was where most of the rodent burrows were observed. These areas provide abundant food (various herbaceous products, including seeds) and shelter. During the fall, *Apodemus* populations expand dramatically to provide enough individuals to overwinter. These grassy areas have numerous species of grasses and herbaceous plants which are seeded out at this time and provide abundant food for the exploding populations. This expansion of *Apodemus* populations also corresponds to the fall HTNV epidemic season. In many cases, the grassy areas were not associated with agricultural practices such as rice farming. A large number of *Apodemus* were also found in scrub areas which also provide abundant food and shelter especially in the fall. *Apodemus* were also found in rice field areas but were usually trapped in areas where there were clumps of grass or reeds to provide shelter and food.

There were no differences between sex or species distribution of *Apodemus* according to habitat. However, *A agrarius mantchuricus* was seen more in agricultural areas, such as gardens, than in rice fields.

There was no difference in distribution of scrub typhus seropositivity by sex, as would be expected with an arthropod borne disease. There was also no difference by

age since most of the trapping was done in the fall, when chigger mites are active, and all age groups are equally exposed (Table 10). As expected, most of the scrub positive animals were trapped in the grassy and scrub areas (Table 11).

Figure 2 shows the locations where scrub antibody positive *Apodemus* were found. This figure indicates that the disease is widespread and poses a threat to military personnel throughout the ROK. A total of 12 isolates were made from *Apodemus* and Figure 4 details the locations. A total of 5 isolates were also made from ROK soldiers. We are in the process of identifying these according to strain.

Distribution of HTNV antibodies in *Apodemus* populations by age and sex shows that adult males are seropositive more than twice as often as females (OR 2.6 [1.6-4.5], $p<0.001$). There were no antibodies found in juveniles and only a very low prevalence in sub-adults. These data suggest that at least within *Apodemus* populations in nature, aerosol or arthropod transmission is not the primary route of infection. Also, in-utero, post partum or transmission of virus by milk does not play a role in the maintenance of the virus in *Apodemus*. Table 13 shows the distribution of antibodies according to habitat. These data show that the risk of acquiring a HTNV infection is most likely in grassy or scrub areas but there is a risk in any habitat.

Figure 4 shows the locations where HTNV antibody positive *Apodemus* were found. This figure indicates that HTNV virus is also widespread throughout the ROK and can pose a threat to military personnel anywhere. A total of 23 HTNV isolates were made from *Apodemus* and Figure 4 details their locations. We are in the process of analyzing these by PCR and restriction endonucleases to determine if there are strain differences between the different locations. A total of 4 isolates were also made from ROK and US soldiers and these will also be analyzed by PCR.

Tables 14 and 15 detail the leptospirosis isolation results from domestic farm animals and sylvatic and urban rodent populations. A total of 16 slaughter houses were sampled and there were no isolations from 307 porcine or 71 bovine kidneys. A total of 478 sylvatic mammals from 22 field sites were cultured. Only 7 isolations were made, 5 from *Apodemus* and 2 from *Rattus*. We concluded that sylavtic mammal populations played only a very minor role in the maintenance of leptospirosis. Therefore, attempts to sample from that population was discontinued after 1990 because of the costs involved in culturing. Attempts to sample more slaughter houses was also discontinued because of political sensitivities from the Korean Agricultural Ministry. It appears from these data that neither domestic farm animals nor sylvatic mammals play an important role in maintenance or transmission of leptospirosis in the ROK. It is well documented that urban rats do play an important role and attempts will be made to sample more urban rodent populations both in large cities and in smaller villages. However, we have been hampered in the past by the fact that *Rattus* populations tend to be very "trap shy" and this makes it difficult to obtain adequate numbers.

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Figure 1. Geozoological survey sites.

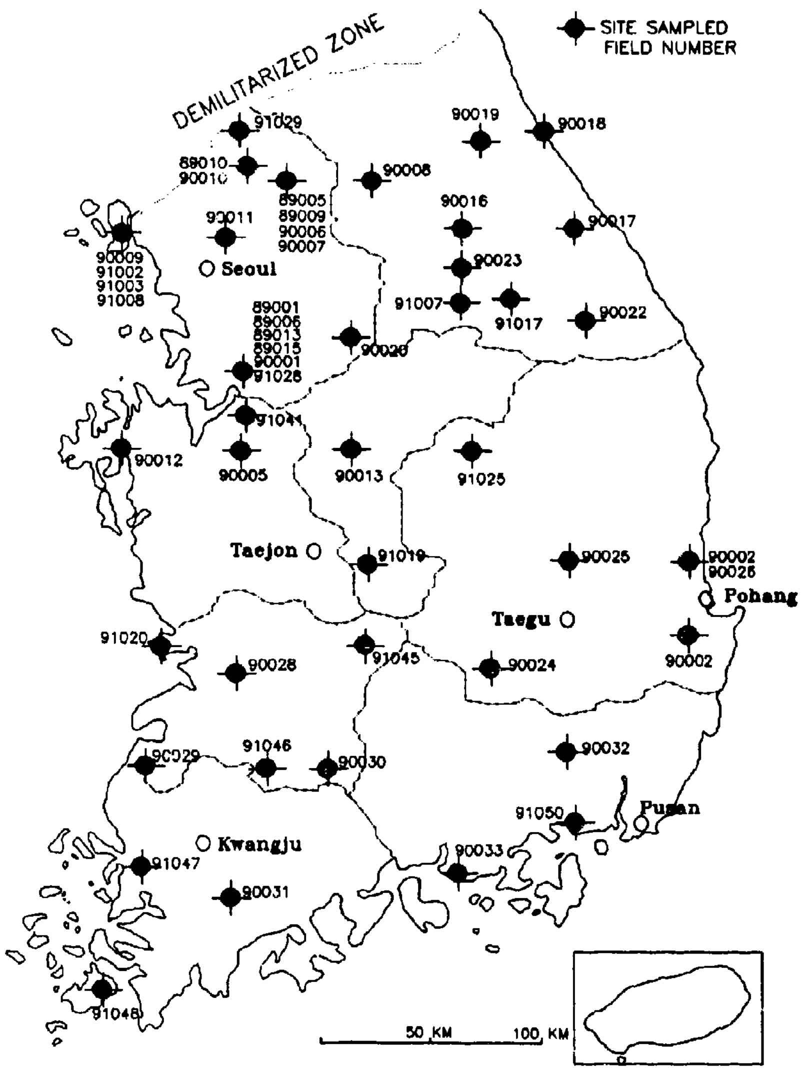


Figure 2. Location of field sites with Apodemus spp. serologically positive for scrub typhus antibodies.

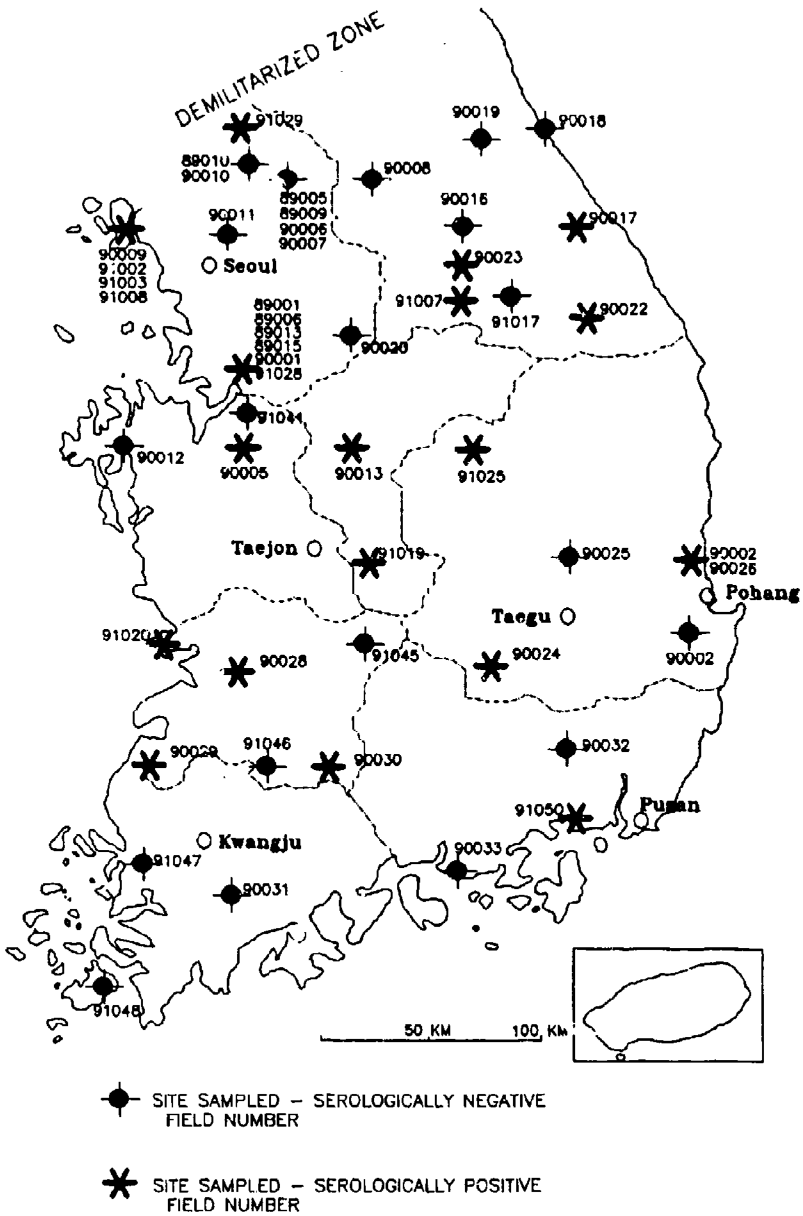


Figure 3. Location of field sites where <u>Rickettsia</u> <u>tsutsugamushi</u> has been isolated from <u>Apodemus</u> <u>spp</u>.

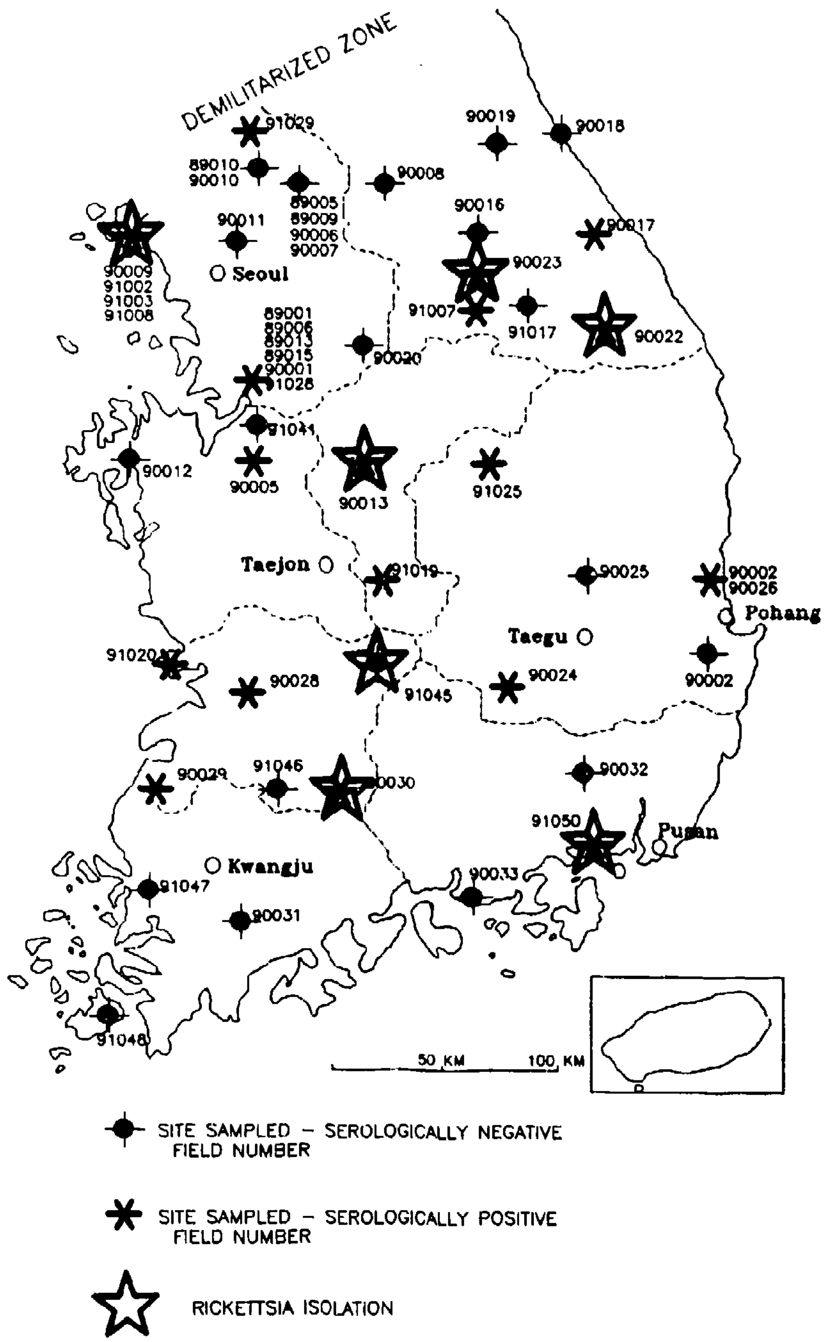
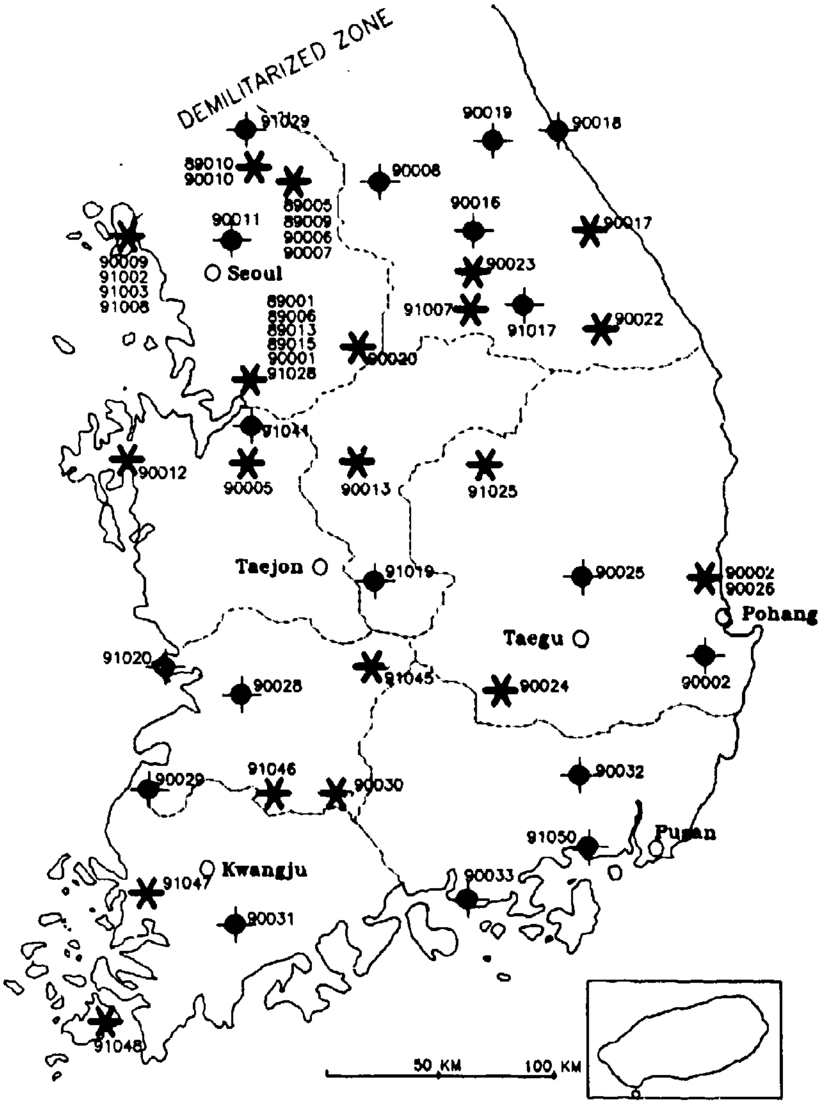


Figure 4. Location of field sites with Apodemus spp. serologically positive for Hantaan antibodies.



SITE SAMPLED – SEROLOGICALLY NEGATIVE
FIELD NUMBER

SITE SAMPLED – SEROLOGICALLY POSITIVE
FIELD NUMBER

Figure 5. Location of field sites where Hantaan virus has been isolated from <u>Apodemus</u> <u>spp</u>.

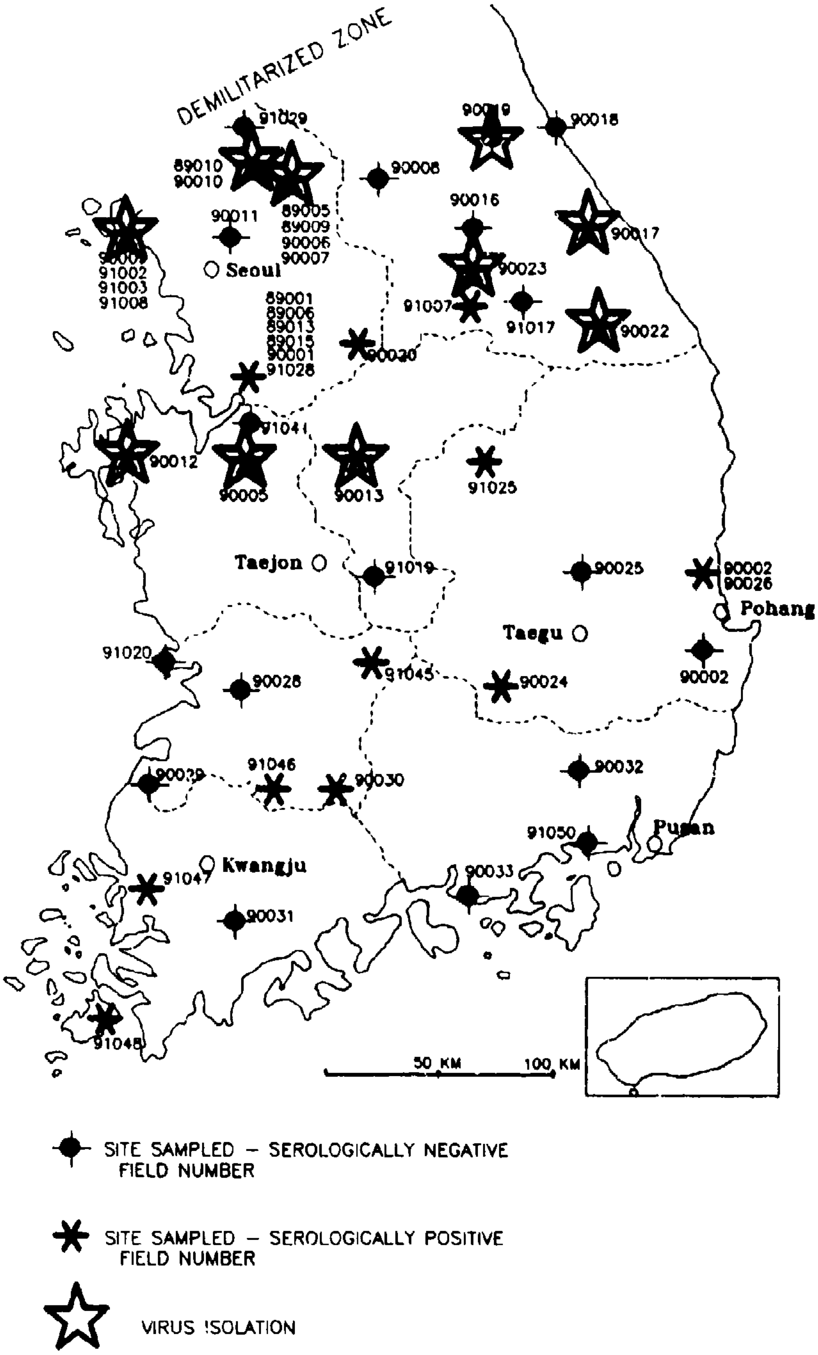


Table 1. Demographics of Leptospirosis Patients Identified at the Capital Armed Forces General Hospital in Seoul, Korea, 11/89 to 1/92

Patient	Age	MOS	Date of Onset	Residences+
1	21	Infantryman	10/23/89	Chungbuk, Jungwon-gun
2	21	Recoilless gunner	9/24/90	Kyonggido, Icheon-gun
				Kyongbuk, Youngcheon-gun
				Kyonggido, Icheon-gun
3	21	Tel. operator	9/24/90	Kyonggido, Yangpyung-gun
4	22	Tank crewman	9/26/90	Kyonggido, Yangpyung-gun
				Kyonggido, Yeoju-gun
5	21	Wire installer	9/27/90	Kyonggido, Yangpyung-gun
6	21	Infantryman	9/27/90	Kyonggido, Yangpyung-gun
7	21	Infantry	10/13/90	Cheonbuk, Namwon-shi
8	20	Infantry	10/24/91	Kyonggi-do, Suwon-shi

+Locations of residences just prior to date of onset of illness

Table 2. Demographics of Scrub Typhus Patients Identified at the Capital Armed Forces General Hospital in Seoul, Korea, 11/89 to 1/92

Patient	Age	MOS	Date of Onset	Residences+
1	22	Infantryman	10/21/89	Kangwondo, Inje-gun
2	22	Infantryman	5/1/90	Kyonggido, Pocheon-gun
3	21	Dispensary aide	9/18/90	Kangwondo, Hongcheon-gun
4	22	Machine gunner	10/9/90	Kangwondo, Chulwon-gun
5	22	Driver	10/16/90	Kangwon-do, Hwacheon-gun
6	23	Musician	11/3/90	Chungnam, Nonsan-gun
7	20	Driver	12/5/90	Seoul, Kangseo-gu
8	23	Artillery	10/1/91	Kyonggi-do, Yeoncheon-gun
9	22	810 (KATUSA)	10/2/91	Kyonggi-do, Dongducheon-shi
10	20	Infantry	10/9/91	Kyonggi-do, Yeoncheon-gun
11	23	Infantry	10/13/91	Seoul, Jongro-gu
12	21	Infantry	10/15/91	Kyonggi-do, Yeoncheon-gun
13	20	Driver	10/18/91	Kangwon-do, Chuncheon-shi
14	23	Infantry	11/22/91	Kangwon-do, Hongcheon-gun

+Locations of residences just prior to date of onset of illness

Table 3. Total number of patients with hemorrhagic fever with renal syndrome (HFRS), murine typhus, scrub typhus, spotted fever group (SFG) rickettsiosis and leptospirosis diagnosed serologically among suspect hemorrhagic fever patients in Korea, 1991

Disease	Civilian*	%	Soldier +	%	Total	%
HFRS	330	(13)	44	(53)	374	(14)
Murine typhus	149	(6)	1	(1.5)	150	(6)
Scrub typhus	376	(14)	1	(1.5)	377	(14)
SFG rickettsiosis	10	(0.4)	0		10	(0.4)
Leptospirosis	15	(0.6)	0		15	(0.6)
Unknown	1736	(66)	17	(27)	1753	(65)

*n=2616

Table 4. Geographical distribution of HFRS, murine typhus, scrub typhus, spotted fever group (SFG) rickettsiosis and leptospirosis among civilian suspect hemorrhagic fever patients in Korea, 1991

Province	HFRS	murine typhus	scrub typhus	spotted fever	leptospirosis
Seoul city	96	65	100	4	9
Kyunggi-do	124	30	76	0	4
Kangwon-do	15	4	18	0	1
Chungcheongbuk-do	9	6	11	0	0
Chungcheongnam-do	39	21	65	4	0
Kyungsangbuk-do	11	6	8	0	0
Kyungsangnam-do	7	4	16	0	0
Jeollabuk-do	17	6	43	0	0
Jeollanam-do	6	3	26	0	0
Cheju-do	0	0	0	0	0
Unknown	6	3	13	2	1
Total	330	149	376	10	15

Table 5. Monthly incidence of HFRS, murine typhus, scrub typhus, spotted fever group (SFG) rickettsiosis and leptospirosis among civilian suspect hemorrhagic fever patients in Korea, 1991

Month	Sera tested	HFRS	murine typhus	scrub typhus	spotted fever	leptospirosis	unknown
1	208	35	14	10	3	0	146
2	94	5	5	1	1	0	77
3	80	0	0	0	0	0	76
4	115	7	7	1	2	0	94
5	148	9	9	0	0	1	117
6	166	26	4	0	0	4	132
7	164	26	10	1	2	3	122
8	119	7	7	0	1	1	103
9	173	7	19	6	0	3	138
10	695	46	46	242	1	3	355
11	451	83	16	108	0	0	253
12	203	52	12	7	0	0	123
Total	2616	330	149	376	10	15	1736
(%)		(13)	(6)	(14)	(0.4)	(0.6)	(66)

Table 6. Age and sex distribution of HFRS, murine typhus, scrub typhus, spotted fever and leptospirosis among civilian patients in Korea, 1991

Age	HFRS			murine typhus			scrub typhus			spotted fever			leptospirosis		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
0-10	0	0	0	1	0	1	3	3	6	0	0	0	0	0	0
11-20	19	6	25	2	1	3	1	1	2	0	0	0	2	0	2
21-30	49	12	61	9	10	19	21	17	38	1	2	3	1	0	1
30-40	60	21	81	14	8	22	33	20	53	4	0	4	1	1	2
41-50	38	12	50	20	7	27	41	32	73	1	0	1	2	0	2
51-60	34	33	67	19	20	39	37	47	84	0	0	0	4	1	5
61-70	14	15	29	17	7	24	25	45	70	0	0	0	3	0	3
71-80	4	2	6	9	3	12	10	22	32	0	0	0	0	0	0
81-90	0	0	0	0	0	0	1	3	4	0	0	0	0	0	0
unk	9	2	11	1	1	2	12	2	14	2	0	2	0	0	0
Total	227	103	330	92	57	149	184	192	376	8	2	10	13	2	15
(%)	(69)	(31)		(62)	(38)		(49)	(51)		(80)	(20)		(87)	(13)	

Table 7. Distribution of Hantaan virus, scrub typhus, murine typhus, spotted fever group antibodies in mammals trapped during the geozoological survey

Mammal	No. mammals trapped	Serology Results*			
		HTN Virus	Scrub typhus	Murine typhus	Spotted fever group
Soricidae	76	0/35	1/35	0/35	0/35
Apodemus agrarius	1,436	70/1159	120/1159	0/1159	30/1159
Apodemus agrarius mantchuricus	18	0/14	1/14	0/14	0/14
Apodemus penninsulae	76	5/62	5/62	0/62	3/62
Clethrionomys rufocanus	3	0/2	0/2	0/2	0/2
Cricetulus trifon	2				
Micromys minutus	10	0/8	0/8	0/8	1/8
Micromys fortis	16	0/10	1/10	0/10	0/10
Mus musculus	10	0/10	0/10	0/10	0/10
Rattus rattus	24	0/17	3/17	0/17	0/17
Rattus norvegicus	4	2/4	4/4	4/4	1/4
Total	1,675	77/1322	135/1322	4/1322	35/1322

* No. IFAT antibody positive / No. tested

Table 8. Serology results by field site for Hantaan virus and scrub typhus on *Apodemus* collected during the geozoological survey

Field Site Identification	Date Collected	Location	Serology Results*	
			Hantaan virus	Scrub typhus
89001	13 Jun 89	Songhwa-ri, Pyongtaek	0/22 (0)	1/22 (4.5)
89005	4 Sep 89	Sangdong, Pocheon	3/28 (10.7)	0/28 (0)
89006	11 Oct 89	Songhwa-ri, Pyongtaek	3/25 (12)	0/25 (0)
89009	23 Oct 89	Sangdong, Pochon	5/54 (9.3)	0/54 (0)
89010	8 Nov 89	Gomun-ri, Yonchon	0/10 (0)	0/10 (0)
89013	23 Nov 89	Songhwa-ri, Pyongtaek	0/21 (0)	4/21 (19.0)
89015	18 Dec 89	Songhwa-ri, Pyongtaek	0/19 (0)	0/24 (0)
90001	8 Jan 90	Songhwa-ri, Pyongtaek	0/19 (0)	0/19 (0)
90002	30 Jan 90	Pohang Area	2/41 (4.9)	0/41 (0)
90005	26 Mar 90	Gwipimal, Chonwon	3/21 (14.3)	4/21 (19.0)
90006	3 Apr 90	Taekak-jae, Jeongok	2/28 (7.1)	0/28 (0)
90007	7 May 90	Taehoesan-ri, Unchon	0/12 (0)	0/12 (0)
90008	28 May 90	Osumul, Chunchon	0/19 (0)	0/19 (0)
90009	11 Jun 90	Yachon, Kanghwa	13/59 (22)	0/59 (0)
90010	21 Jun 90	Sorun-ri, Pochon	4/25 (16)	2/25 (8)
90011	28 Jun 90	Kyoyeon-ri, Yangju	0/21 (0)	0/21 (0)
90012	9 Jul 90	Haipsok, Sosan	2/33 (6.1)	0/33 (0)
90013	18 Jul 90	Jayang, Goesan	9/45 (20.0)	4/45 (8.9)
90016	3 Sep 90	Panggadae, Hongchon	0/4 (0)	0/4 (0)
90017	5 Sep 90	Chongnyonam, Pyongchang	5/14 (35.7)	0/14 (0)
90018	17 Sep 90	Yaepo, Sokcho	0/13 (0)	1/13 (7.7)
90019	19 Sep 90	Yongsugol, Inje	0/9 (0)	0/9 (0)
90020	10 Oct 90	Yoju	3/9 (33.3)	0/9 (0)
90022	16 Oct 90	Wapyong, Chongson	2/22 (9.1)	6/22 (27.3)
90023	17 Oct 90	Changmal, Hoengsong	4/19 (21.1)	2/19 (10.5)
90024	29 Oct 90	Chipsil, Songju	2/39 (5.1)	1/39 (2.6)
90025	30 Oct 90	Hantijae, Uisong	1/12 (8.3)	0/12 (0)
90026	6 Nov 90	Pohang Area	0/6 (0)	2/6 (33.3)
90028	12 Nov 90	Ungok-ri, Wanju	0/63 (0)	13/63 (20.6)
90029	14 Nov 90	Dosan-ri, Kochang	0/49 (0)	13/49 (26.5)
90030	26 Nov 90	Maesan, Namwon	3/38 (7.9)	25/38 (65.8)
90031	28 Nov 90	Pyoksong-ri, Hwasun	0/34 (0)	0/34 (0)
90032	3 Dec 90	Hangol, Miryang	0/11 (0)	0/11 (0)
90033	5 Dec 90	Sangchon, Sachon	0/12 (0)	0/12 (0)
91002	21 Jan 91	Kanghwa	1/21 (4.8)	2/21 (9.5)
91003	19 Feb 91	Kanghwa	2/6 (33.3)	1/6 (16.7)
91007	9 Mar 91	Camp Long	1/81 (1.2)	2/81 (2.5)
91008	20 Mar 91	Kanghwa	0/9 (0)	0/9 (0)
91019	29 Apr 91	Gugeon-ri, Okchon	0/16 (0)	12/16 (75.0)
91020	30 Apr 91	Chilsong-dong, Kunsan	0/14 (0)	9/14 (64.3)
91025	17 Jun 91	Gwaneum-ri, Mugyong	0/12 (0)	2/12 (16.7)
91028	12 Sep 91	Songhwa-ri, Pyongtaek	0/14 (0)	2/14 (14.3)
91029	25 Sep 91	Sochonmal, Cholwon	0/30 (0)	10/30 (33.3)
91041	29 Sep 91	Songhwa-ri, Pyongtaek	0/22 (0)	0/22 (0)
91045	11 Nov 91	Arletbirisil, Mujoo	1/45 (2.2)	0/45 (0)
91046	12 Nov 91	Unbuk-ri, Sunchang	1/17 (5.9)	0/17 (0)
91047	13 Nov 91	Heungryong-dong, Hampyong	1/25 (4.0)	0/25 (0)
91048	14 Nov 91	Nonsudong, Jindo	2/41 (4.9)	0/41 (0)
91050	3 Dec 91	Yojwa-dong, Jinhae-si	0/21 (0)	10/21 (47.6)

* No. IFAT positive / No. sampled (%)

Table 9. Distribution of *Apodemus* trapped during the geozoological survey by habitat

Habitat type	*Apodemus agararius*	*A. agararius mantchuricus*	*A. peninsulae*
Wood line	61	0	8
Scrub	285	3	14
Field layer	768	8	36
Open ground	55	0	4
Aquatic-terrestrial	53	0	1
Rice field	135	0	11
Agriculture	39	7	1
Unknown	40	0	1

Woodline type, includes mature trees over 4 m; Scrub type, includes scrub, scrubs, reeds, and saplings, 1 m to 2 m; Field layer type, includes tall grasses and low herbs, some low shrubs, 0.2 m to 1 m; Open ground type, includes cropped and mown grassland, fallow fields, bare ground, less than 0.2 m; Aquatic-terrestrial transition, includes edges of streams, rivers and lakes; Rice fields including surrounding embankments; Agriculture crops, includes corn, milo, truck crops.

Table 10. Distribution of scrub typhus antibodies in *Apodemus spp*. collected during the geozoological survey, by age and sex

	Juvenile	Sub-Adult	Adult	Total
Male	6/96* (6.2)	24/225 (10.7)	38/317 (12.0)	68/638 (10.7)
Female	1/81 (1.2)	23/227 (10.1)	34/283 (12.0)	58/591 (9.8)
Total	7/177 (4.0)	47/452 (10.3)	72/600 (12.0)	126/1229 (10.2)
	P=.19	P= .88	P =1.0	

*No. IFAT positive / No. tested (%)

Table 11. Distribution of scrub typhus antibodies in *Apodemus spp*. collected during the geozoological survey by habitat, age and sex

Habitat type	Juvenile		Sub-Adult		Adult	
	Male	Female	Male	Female	Male	Female
Wood line	0/2*	0/3	0/9	0/10	2/14 (14.3)	1/13
Scrub	0/13	0/16	1/50 (2.0)	6/35 (17.1)	14/73 (19.2)	7/67 (10.4)
Field layer	5/52 (9.6)	1/42 (2.4)	21/132 (15.9)	14/121 (11.6)	20/124 (16.1)	18/143 (12.6)
Open ground	0/2	0/2	0/5	0/9	1/29 (3.4)	0/9
Aquatic-terrestrial	0/1	0/4	0/9	0/11	0/20	0/4
Rice field	0/17	0/10	1/13 (7.7)	1/25 (4.0)	0/39	3/27 (11.1)
Agriculture	1/9 (11.1)	0/4	1/1 (100)	0/2	1/7 (14.3)	4/15 (26.7)
Unknown			0/6	2/14 (14.3)	0/11	2/5 (40.0)

Woodline type, includes mature trees over 4 m; Scrub type, includes scrub, scrubs, reeds, and saplings, 1 m to 2 m; Field layer type, includes tall grasses and low herbs, some low shrubs, 0.2 m to 1 m; Open ground type, includes cropped and mown grassland, fallow fields, bare ground, less than 0.2 m; Aquatic-terrestrial transition, includes edges of streams, rivers and lakes; Rice fields including surrounding embankments; Agriculture crops, includes corn, milo, truck crops.

* No. IFAT positive / No. tested (%)

Table 12. Distribution of Hantaan virus antibodies in *Apodemus spp.* collected during the geozoological survey, by age and sex

	Juvenile	Sub-Adult	Adult	Total
Male	0/96* (0)	2/225 (0.8)	52/317 (16.4)	54/638 (8.5)
Female	0/81 (0)	3/227 (1.3)	17/283 (6.0)	20/591 (3.4)
Total	0/177 (0)	5/452 (1.1)	69/600 (11.5)	74/1229 (6)
		P= .9	P < .01	

*No. IFAT positive / No. tested (%)

Table 13. Distribution of Hantaan virus antibodies in *Apodemus spp.* collected during the geozoological survey by habitat, age and sex

Habitat type	Juvenile		Sub-Adult		Adult	
	Male	Female	Male	Female	Male	Female
Wood line	0/2*	0/3	0/9	0/10	1/14 (7.1)	1/12 (7.7)
Scrub	0/13	0/16	0/50	1/35 (2.9)	18/73 (24.7)	6/67 (9.0)
Field layer	0/52	0/42	1/132 (0.8)	2/121 (1.7)	18/124 (14.5)	4/143 (2.8)
Open ground	0/2	0/2	0/5	0/9	2/29 (6.9)	1/9 (11.1)
Aquatic-terrestrial	0/1	0/4	0/9	0/11	5/20 (25.0)	1/4 (25.0)
Rice field	0/17	0/10	0/13	0/25	5/39 (12.8)	3/27 (11.1)
Agriculture	0/9	0/4	0/1	0/2	3/7 (42.9)	1/15 (6.7)
Unknown			1/6 (16.7)	0/14	0/11	0/5

Woodline type, includes mature trees over 4 m; Scrub type, includes scrub, scrubs, reeds, and saplings, 1 m to 2 m; Field layer type, includes tall grasses and low herbs, some low shrubs, 0.2 m to 1 m; Open ground type, includes cropped and mown grassland, fallow fields, bare ground, less than 0.2 m; Aquatic-terrestrial transition, includes edges of streams, rivers and lakes; Rice fields including surrounding embankments; Agriculture crops, includes corn, milo, truck crops.

* No. IFAT positive / No. tested (%)

Table14. Isolation results for leptospirosis from domestic animal kidneys collected at slaughter houses, by location

Field Site Idnetification	Date Collected	Slaughter house Location	Isolation Results* Swine	Bovine
91004	27 Feb 91	Pyongtaek	0/25	0/10
91006	5 Mar 91	Shinpung-ri, Yochon	0/26	0/10
91009	2 Apr 91	Andong	0/20	0/3
91010	3 Apr 91	Yangsan	0/20	0/10
91011	9 Apr 91	Kochang	0/20	0/10
91012	10 Apr 91	Hadong, Hamyang	0/9	0/1
91013	11 Apr 91	Yangsan-dong, Kwangju	0/19	0/10
91014	12 Apr 91	Kyohon-ri, Kochang	0/14	0/1
91015	13 Apr 91	Chonju-si	0/19	0/3
91016	16 Apr 91	Taejon-si	0/22	0
91017	17 Apr 91	Chongju-si	0/23	0/8
91018	15 Apr 91	Kanghwa	0/15	0/2
91021	2 May 91	Kuamdong, Kunsan	0/20	0
91022	3 May 91	Bosong, Sosan	0/15	0
91023	13 May 91	Chunchon-si	0/19	0/3
91024	16 May 91	Sokcho-si	0/21	0
Total			0/307	0/71

*No. culture positive / No. collected

Table 15. Isolation results for leptospirosis from rodent kidneys collected during the geozoological survey, by field site and species

Field Site Identification	Date Collected	Location	*Apodemus*	*Rattus*	*Soricidae*	*Micromys*	*Mus*	*Clethrionomys*
89014	5 Jan 90	Yongsan, Seoul		2/14				
90002	30 Jan 90	Pochang Area	0/39*			0/3		
90007	7 May 90	Taehoesan-ri, Unchon	0/25					
90008	28 May 90	Osumul, Chunchon	0/19					
90009	11 Jun 90	Yachon, Kanghwa	0/45	0/1				
90010	21 Jun 90	Sorun-ri, Pochon	0/16				0/2	
90011	28 Jun 90	Kyoyeon-ri, Yangju	0/15					
90012	9 Jul 90	Hapsok, Sosan	0/26					
90013	18 Jul 90	Jayang, Goesan	0/39					
90016	3 Sep 90	Panggadae, Hongchon	0/4		0/1		0/1	
90017	5 Sep 90	Chongnyonam, Pyongchang	0/10					
90018	17 Sep 90	Yaepo, Sokcho	0/13		0/2			0/1
90019	19 Sep 90	Yongsugol, Inje	0/8					
90020	10 Oct 90	Yoju	1/9		0/1		0/1	
90022	16 Oct 90	Wapyong, Chongson	0/21					
90023	17 Oct 90	Changmal, Hoengsong	0/19					
90024	29 Oct 90	Chipsil, Songju	0/38					
90025	30 Oct 90	Hantijae, Uisong	0/12		0/1			
90028	12 Nov 90	Ungok-ri, Wanju	3/28					
90029	14 Nov 90	Dosan-ri, Kochang	0/23					
90030	26 Nov 90	Maesan, Namwon	0/18					0/1
90031	28 Nov 90	Pyoksong-ri, Hwasun	1/20					
Total			4/449	2/15	0/5	0/3	0/4	0/2

* No. culture positive / No. sampled (%)

Publications

1. Dixon KE, Nang RN, Kim DH, et al. Comparison of case cross-over versus classic case-control analysis method. Am J Epidemiol, 134 (7); 757, 1991.

2. Dixon KE, Nang RN, Kim DH, et al. A case-control study of risk factors for Korean hemorrhagic fever among soldiers in the Republic of Korea. Am J Trop Med Hyg, (Suppl. 3); 255, 1991.

3. Lee HW, Baek LJ, Ahn CN. Global distribution of hantaviruses and hemorrhagic fever with renal syndrome. 2nd Int'l Cong. HFRS. Beijin, Abstract p2, 26-28 Oct. 1992.

4. Arthur JD, Graham RR, Cheong TW, Hwang YJ, Yi KS. Urban scrub typhus in the Republic of Korea (Accepted for publication in Lancet), 1993.

5. Lee JY, Chang H, Graham RR, Cheong TW, Hwang YJ, Nang RN, Arthur JD. Operational serosurvey in ROK Soldiers (in preparation), 1993.

6. Dixon KE, Nang RN, Kim DH, Hwang YJ, Park JW, Huh JW, Cho YK. A hospital-based case control study of risk factors for Korean Hemorrhagic Fever in Soldiers of the Armed Forced of the Republic of Korea (in preparation), 1993.

7. Dixon KE, Nang RN, Hwang YJ, Park JW. Use of the case crossover method to study risk factors for Korean Hemorrhagic Fever (in prepration), 1993.

8. Dixon KE, Manthos C. The incubation period of Korean Hemorrhagic Fever (in preparation), 1993.